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DEFORMATION OF DOLOMITE SINGLE CRYSTALS FROM 20 - 800°C

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The stress-strain behaviour of single crystal dolomite has been determined in uniaxial compression at 700 MPa effective pressure, 20° to 800°C, and at a strain rate of $1\cdot 3 \times 10^{-5}\ s^{-1}$. Six orientations of the principal stress axis to the crystallographic symmetry axes were tested as shown in Figure 1:

(1) 60° to c, 74° to r

(2) // c

(3) 15° to m in m zone

(4) 60° to c near f

(5) // a

(6) 45° to c in a zone

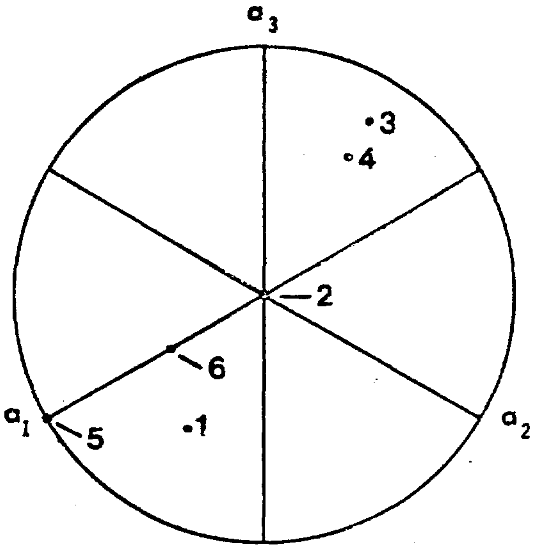

Figure 1

Comparison of the resulting stress-strain curves for each orientation indicates that dolomite is strongly anisotropic, with the strength increasing with temperature in five of the six orientations shown in Figure 1. In these five, the principal stress difference (at 2% permanent strain) increases by a factor of 1.5 to 2.5 over 780°C, with minor deviations. But for orientation No. 5 the strength decreases by a factor of 2 over the same temperature interval. These results are illustrated in abbreviated form in Figure 2. This shows, on the left, plots of principal stress difference versus strain for several temperatures for orientation No. 5 and, on the right, the variation of the principal stress difference (at 2% strain) with temperature for orientations No's 1, 2, 3, 4, 5 & 6.In all orientations except No. 2, which favours twinning, the test pieces were found to have deformed by slip. Pre-annealing of the dolomite at 500°C usually produces a decrease in the strength (compared to the unannealed material), by up to a factor of 2, but this effect is shown only in the region of 20° to 250°C.

Optical and HVEM/TEM methods have broadly confirmed the earlier findings of Fairbairn and Hawkes (1941) and Higgs and Handin (1959) that dolomite twins on $\underset{\sim}{f} \equiv (\bar{1}012)$ and slips on $\underset{\sim}{c} \equiv (0001)$. Our results for orientations No's 1 and 4 confirm the increase in strength with temperature up to 500°C for $\underset{\sim}{c}$ slip as

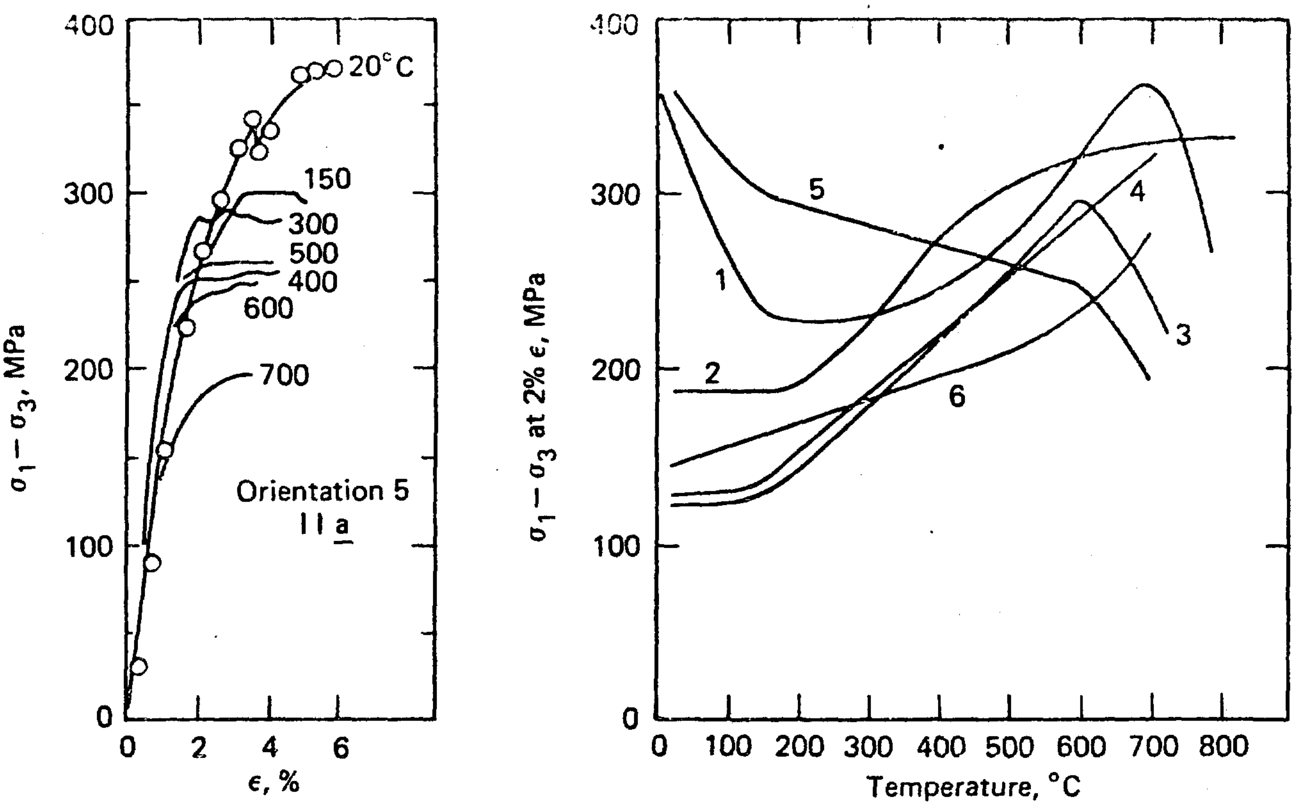

Figure 2

reported by Higgs and Handin (1959). However, our data also show an increase in strength with temperature for f twinning, which is strongly favored in orientation No. 2.

We have additionally found that slip on f is an important mechanism at > 300°C and that slip on r ≡ $(10\bar{1}4)$ occurs at high temperatures (∿ 600°C), although it is never dominant. Twinning does not occur below ∿ 300°C, and it dies out above 600°C. The senses of f slip and f twinning are opposite, the former being in the positive sense in the $[02\bar{2}1]$ or $[\bar{2}201]$ directions and the latter being in the negative sense in the $[10\bar{1}1]$ direction.

Optical analysis shows that in those orientations conducive to r translation, basal deformation bands develop at low temperature. These bands contain mainly open fractures parallel to $(10\bar{1}0)$. At higher temperature (400-600°C) diffuse prismatic kinkbands develop. Specimens with a high resolved shear stress on f develop narrow (< .002 mm) twins which are generally less than 1 mm long and terminate within the crystal. Particularly at high temperature f cracking becomes very pronounced.

With TEM we can document in the mid-temperature range (400-500°C) that the dislocation behaviour on the r and f planes is somewhat similar (which incidentally means that we must seek a wider explanation for the opposite temperature dependences of strength v. temperature in specimens oriented to favour r and f slip): large numbers of pairs of partial dislocations are formed and many become widely separated, creating long ribbons of stacking faults. Aggregates of point defects collect where partials are temporarily arrested, making subsequent motion difficult (which probably accounts for the long stacking faults). The model which we favour for f partial dislocations (with Burgers vector $1/6[02\bar{2}1]$) suggests that their passage creates disorder in the carbonate groups which is not restored by the traversal of the trailing partial. This model is supported by strong residual contrast from active f slip planes. The passage of partial dislocations (with Burgers vector $1/3\langle 1\bar{1}00\rangle$) on the basal planes does not seem to induce permanent disorder.

Twinning on $\underset{\sim}{f}$ is operative over a similar temperature range to the appearance of stacking faults, in general agreement with the common correlation of twinning with stacking fault energy in ordered compounds. Although twins in dolomite can occur without the creation of large numbers of associated dislocations (as usually occurs in calcite), specimens compressed in orientation No. 2, which favours twinning, nevertheless exhibit considerable amounts of slip. Low temperature tests produce heterogeneous basal slip and cracking, mid-temperature tests give rise to profuse twinning (usually on all three $\underset{\sim}{f}$ systems) and basal slip, and tests above 500°C exhibit complex slip behaviour, minor twinning and increasing evidence of climb with temperature.

Specimens which were tested in orientation No. 1 show marked changes in deformation mechanisms as test temperature is increased. At low temperatures heavy slip bands are separated by undeformed layers of crystal, but there is much transverse cleavage and fracture. At $\sim$ 200°C, cracking is much reduced and basal slip is usually homogeneous and pervasive. At > 200°C, minor f slip occurs additionally and at $\sim$ 400°C basal stacking faults occur. At $\sim$ 500°C cross-slip between $\underset{\sim}{f}$ and $\underset{\sim}{c}$ commonly occurs to overcome obstacles and dislocation tangles which arise from the interference of dislocations gliding on $\underset{\sim}{c}$, $\underset{\sim}{f}$ and occasionally $\underset{\sim}{r}$. Interactions also generate increasing densities of small loops and other debris in the slip planes as the testing temperature rises above 400°C. Evidence of climb can be seen at temperatures $\sim$ 600°C, and although its effects are more pronounced at 700°C and 800°C, the dislocation densities remain very high, in accord with the high strengths and work-hardening exhibited in the tests.

Specimens in orientation No. 4 exhibit a more simple behaviour than those in orientation No. 1. In the former, the resolved shear stress on the basal planes remains high compared with No. 1, while the resolved shear stresses on other possible slip systems are much lower than in orientation No. 1. In accordance with these facts, HVEM examination has shown that $\underset{\sim}{c}$ slip is the predominant mechanism in orientation No. 4 up to 700°C, when the effects of climb become important.

Orientation No. 5 has the effect of applying large and equal shear stresses on two sets of $\underset{\sim}{f}$ planes in <0$\overline{22}$1> directions. HVEM has shown that throughout the range of testing temperatures in these spcimens, one of the $\underset{\sim}{f}$ slip systems has been strongly activated while the other is subordinate. This specimen orientation is the one which shows a reduction in strength versus temperature (Figure 2), so that the effect is undoubtedly associated with $\underset{\sim}{f}$ slip. Climb effects again become very obvious at 700°C.

Fairbairn, H.W. and Hawkes, H.E. (1941) Am. J. Sci. 239, 617-632.

Higgs, D.V. and Handin, J. (1959) Bull. Geol. Soc. Am. 70, 245.

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